A NEW PRINCIPLE IN HELIOCHROMY

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BY

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PREFACE.

The following pages contain a concise statement of the principles and practice of a process by which it is possible to produce photographs in natural colors, prefaced by a brief introduction, and followed by a comparison with, and criticism of, a method proposed by Dr. H. W. Vogel.

The author has not seen fit to enter into such detailed explanation of the modern theory of light and color vision as may seem desirable, but prefers to refer the unscientific reader to such text books as Prof. A. H. Church's *Color*, and Prof. O. N. Rood's *Modern Chromatics*, wherein will be found a full and authoritative statement of those theories and principles.

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A NEW PRINCIPLE IN HELIOCHROMY.

There are two kinds of methods by which attempts have been made to produce photographs in natural colors. In the first kind, the rays of light produce the colors by their action upon peculiar sensitive compounds. In the second kind, the action of light does not produce the colors, but is made to regulate their distribution in a photographic picture, automatically, through the operation of the process according to a fixed plan.

By methods of the first kind, the colors are natural in the sense of having been produced by the action of the colored rays of light; but it does not follow that they are, or under any circumstances should be, natural in the sense of being like the colors which acted to produce them.

In methods of the second kind, colors may be employed which are natural in the sense that they represent the primary color-sensations, and are therefore capable of combination so as to reproduce all color effects; but it has been an open question whether any process could be devised which would make the action of the light rays themselves select and combine such type colors correctly.

The first kind of method is represented by a process employing chloride of silver sensitive plates, which will, under certain conditions, imperfectly reproduce some of the colors of the spectrum. This property of chloride of silver was first discovered by Dr. Seebeck, of Jena, in 1810, and the process was more or less modified, after the discovery of the daguerreotype, by Sir John Herschel, Edmond Becquerel, Neipce de St. Victor, Poitevin, and St. Florent. Under the most favorable conditions, these plates require hours of exposure in the camera, and will not reproduce either black, white or yellow; bright red comes out a dull brick color, and green and blue have a metallic hue. The colors cannot be fixed, but fade away in daylight.

The second kind of method was first suggested by Henry Collen, Queen Victoria's teacher of drawing, in 1865. Collen, who accepted Sir David Brewster's theory of three primary colors of light, suggested that if it should ever be possible to make one photographic negative by the action of red light, one by the action of yellow light, and one by the action of blue light, then transparent color prints might be made by printing from each pair of these negatives in combination, —a red print from the negatives made by blue and yellow light, yellow from the blue and red, and blue from the red and yellow,—and superimposed on a white surface, to reproduce the light and shade and colors of the object photographed.* After the discovery

*British Journal of Photography, Oct. 27, 1865, p. 547.

of color-sensitive plates, processes of this character were devised and carried out by Ducos du Hauron of Paris, Albert of Munich, and others, but they were not based upon a true principle, and did not succeed. Nevertheless, Collen's idea contained a germ which has grown and borne fruit, as he himself suggested that it might. Pictures which do truly show the light and shade and all the colors of the object photographed can be produced by a process of this character, which is not based upon Brewster's theory of color, but upon that of Young, Helmholtz and Maxwell.

According to this theory, which is now accepted by all scientific authorities, there are, strictly speaking, hundreds of primary spectrum colors, but only three primary color-sensations. All color sensation is supposed to be due to the excitation of three kinds of nerve fibrils in the eye, one kind producing the sensation of red, another of green, and another of blue. One end of the spectrum affects only the "red fibrils," the other, only the "blue fibrils." The middle of the spectrum affects chiefly the "green fibrils," and intermediate parts affect two kinds of nerve fibrils simultaneously, in different degrees. When all three sets of nerve fibrils are affected alike, the sensation is that of white light.

After much experiment, originally based upon an experimental demonstration of what could be accomplished in the way of counterfeiting complex colors by the mixture of type colors selected arbitrarily, I finally

arrived at a new principle, which is fully in accord with this theory, and undoubtedly a truly scientific solution of the problem. This principle may be conveniently stated as that of producing sets of heliochromic negatives by the action of light rays in proportion as they affect the sets of nerve fibrils in the eye, and images or prints from such negatives with colors which represent the primary color sensations. But the intensity of photographic negatives never varies exactly as the sum of the light which acts to produce them, and this natural defect of all negative making processes introduces a slight complication, on account of which the principle may be more exactly stated as that of producing sets of negatives by the action of light rays in such proportion as will secure a correct representation of their action upon the sets of nerve fibrils, etc.

A set of negatives approximating to the required character can be made by exposing an ordinray gelatine bromide plate through a double screen of chrysophenine yellow (light) and RR methyl violet, a commercial orthochromatic plate (erythrosine-cyanine) through a screen of brilliant yellow, and a special cyanine plate through a screen of deep chrysoidine orange. But in order to secure exact results, color-screens of complex composition must be used, which have been adjusted by experiment in photographing the spectrum itself, until negatives are obtained which show curves of intensity exactly like the curves of a diagram which correctly represents the action of the spectrum upon

the sets of nerve fibrils in the eye. Such a diagram is here shown:

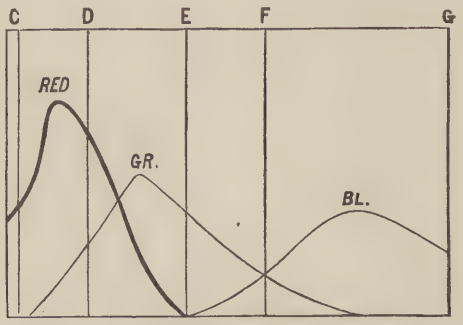

FIG. 1.—Curves of Normal Eye. (Maxwell.)

It is evident that a process which will produce negatives exactly representing the intensity of action of any part of the spectrum upon a set of nerve fibrils in the eye by a corresponding degree of opacity of deposit on that part, will produce negatives which represent, in the same way, the action of light from any source, upon the same set of nerve fibrils. From a set of negatives which thus represent the action of the spectrum upon the sets of nerve fibrils in the eye, a correct heliochrome of the spectrum can be made: from a set of negatives which thus represent the action of a landscape or other object upon the sets of nerve fibrils in the eye, a correct heliochrome of that landscape or other object can be made. It is true that, owing to that defect in negative making processes which has already been mentioned, the most perfect

reproductions will be made only from objects which do not present very great contrasts of light and shadow; but with suitable plates, exposure and development, there should be always a very close approximation to exact representation throughout every shade of the picture.

In the reproduction of art objects, the heliochromic negatives may be made with an ordinary camera, one after another; but for landscape work, where the lights and shadows are ever-changing, it is evidently important that they should be made simultaneously. This is accomplished by means of a triple camera, devised by me for this purpose. With this camera, the three negatives are made from points of view included in a one-and-a-quarter inch circle.

There are two ways in which the heliochromic pictures can be made from the heliochromic negatives. The easiest method is one which does not produce permanent pictures, but only images projected upon the screen; it is, however, a strictly scientific method, and most valuable for demonstration purposes. Ordinary lantern positives are made from the heliochromic negatives, and projected upon the screen by means of a triple optical lantern,—one, with that kind of red light which affects only the red nerve fibrils, one with that kind of green which affects chiefly the green nerve fibrils, and one with the blue-violet, which affects only the blue nerve fibrils. The three images must, of course, be exactly superimposed upon the screen.

Assuming that the lantern positives exactly reverse the light and shade of the negatives, as they should, it is evident that, under the conditions stated, light capable of exciting only one kind of nerve fibrils will be transmitted by each positive, in proportion as light reflected from the object photographed would excite the same kind of nerve fibrils; and the light transmitted by all three positives will combine to produce upon the screen a perfect counterfeit of the light and shade and colors of the object.

It should be noted here that the shades of spectrum red and green which most powerfully excite the red and green nerve fibrils are not the ones which most exclusively affect them, and the pictures are therefore not projected by exactly those rays which were most active in producing them. By reference to Maxwell's diagram, on p. 5, it may be seen that while the orange red of the spectrum affects most powerfully the red nerve fibrils, and the yellow green affects most powerfully the green nerve fibrils, the red color-sensation is represented by rays lower in the spectrum (C), which affect the red nerve fibrils exclusively, and the green color-sensation by rays higher in the spectrum (E), which affect the green nerve fibrils exclusively. Such colored lights are obtained in the lantern by filtering the light of the incandescent lime through suitable color-screens.

Up to this point, the process is operated in strict accordance with all theoretical requirements, and even

with the comparatively imperfect adjustments which are all that I have yet found time to accomplish, wonderful results have been obtained. It is, however, evidently desirable that the process be extended to the production of fixed pictures, on paper and glass, and this extension involves some further complications. Pigment prints must be made from the heliochromic negatives, and inasmuch as the mixture of pigments adds shade to shade instead of light to light, pigments must be used the colors of which are complementary to those rays of the spectrum which represent the primary color-sensations. These pigments do not show curves of absorption corresponding to the curves of intensity in the heliochromic negatives of the spectrum, but similar curves with the highest part removed to those parts of the spectrum which most exclusively affect the corresponding sets of nerve fibrils. Such colors are prussian blue, eosine red and brilliant yellow. Prints properly made in these colors,—blue from the negative representing the red color-sensation, red from the negative representing the green color-sensation, and yellow from the negative representing the blue color-sensation,—when superimposed on a white surface, show the light and shade and colors of the object photographed almost as perfectly as the triple lantern projections.

There is much yet to be done in perfecting the print-making part of the process. For the present, I am satisfied to obtain perfect heliochromic prints on

glass, so that the results may be shown with the optical lantern, and have adopted the following procedure: The blue print is made by the cyanotype process, in a film of gelatine attached to glass. The red print is made by the so-called carbon process, with eosine for the coloring matter,—a reversed print being thereby produced upon another glass. The yellow print is made by the collotype printing process, on a specially prepared film of collodion and gelatine. Several of the red and yellow prints are made, and such prints selected as are found to produce a neutral black in the shadows when superimposed, with the blue print, over a white surface; the colors are then correct in every shade of the picture. After placing the yellow film-picture between the blue and red pictures on glass, and therefore in contact with them, they are moved until the images are exactly superimposed, and then fastened together by binding, to complete the lantern slide heliochrome. I hope to finally employ the Woodbury relief printing process for producing lantern heliochromes in quantities.

[From the *Journal of the Franklin Institute*, February, 1889.]

A COMPARISON.

To the Committee on Publications.

GENTLEMEN:—Having observed, in a communication to the *Photographic News*, a criticism of certain claims which I made in a paper read before the FRANKLIN INSTITUTE, in November last [JOURNAL OF THE FRANKLIN INSTITUTE, January, p. 54], I addressed the following reply to the editor of that journal, and would like to have the same published also in the JOURNAL OF THE FRANKLIN INSTITUTE. F. E. IVES.

Mr. C. H. Bothamley, in the *Photographic News*, January 11th, says: "Recently Ives has described a process of heliochromy, of which he says, 'I claimed for this process that unlike any similar process yet suggested, it was based upon a true conception of the nature of light and color-vision, and was a strictly scientific method of accomplishing the object sought after.' Now, as a matter of fact, a strictly scientific process of the same character was described by Dr. Vogel, in 1885. Moreover, Vogel's process does not differ very greatly from the later process of Ives."

By this time, I am well used to having my original inventions and discoveries claimed for others, but I am surprised that so intelligent a writer as Mr. Bothamley should have failed to see at once that there is a very, very great difference between Dr. Vogel's process and my own. It is even somewhat amusing to know that while some are professing not to be able to see any essential difference between my principle and that of Hauron, others may be equally unable to see the difference between it and one that calls for the production of more than twice as many negatives, and in no way, even remotely, suggests my plan of representing most of the primary spectrum colors by color mixtures. I am sure a comparison of the three methods must make it evident to any unprejudiced person that each one is vitally different from either of the others.

Hauron's principle, as nearly as I have been able get at it, was simply that of making sets of heliochromic negatives by exposing sensitive plates through "orange, green and violet glasses," and from these negatives, prints in blue, red and yellow pigments, superimposed on a white surface. Although no approved theory of the nature of light and color-vision warrants such an

assumption, Hauron assumed that this method should produce pictures correctly reproducing the light and shade and color of the objects photographed.

Dr. Vogel's principle is stated by Mr. Bothamley, in the *Photographic News*, September 9, 1887, as follows: "Vogel proposes to make a much larger number of images, and to use sensitizers corresponding with every region of the spectrum—for example, napthol blue for red, cyanine for orange, eosine for yellow, safranine for green, and fluorescein for bluish green, the ordinary sensitiveness of the plate being sufficient for blue and violet. In taking the negatives the intensity of the blue and violet must be reduced by means of a yellow screen. The fragmentary images thus obtained are transferred to stones, and each is printed in a color complementary to that part of the spectrum to which the particular plate was sensitive. This complementary color is found, however, in the dye which is used to sensitize the plate." Mr. Bothamley adds, "It is obvious that the greater the number of spectrum regions represented by separate images in this way, the more accurate will be the reproduction of the different shades and variations of color." In short, Dr. Vogel's principle really calls for a different negative and print for each primary spectrum color, of which there may be said to be either seven or a thousand, although even at the least estimate, which is quite unscientific, the number is already so great as to make the process absolutely unworkable wherever it is necessary to expose all the plates simultaneously, as in landscape photography. It is also certain that no known color-sensitizers will sensitize bromide of silver for such narrow bands of the spectrum exclusively. The process is not scientific, because it is impossible. My own method is perfectly distinct from Hauron's, in that I do not expose sensitive plates through "orange, green and violet glasses," and from Vogel's, in that I do not make separate negatives for each region of the spectrum, but only three, and in such a manner as to secure curves of intensity which correspond to the action of the light rays upon the sets of nerve fibrils which produce color-sensation. This, in fact, is my principle, which is undoubtedly new and true, and is carried out by exposing color-sensitive plates through compound color-screens, which have been adjusted by experiment in photographing the spectrum itself, until they yield negatives having curves of intensity like the curves of a diagram correctly representing the action of the spectrum upon the sets of nerve fibrils in the eye. A knowledge of the true nature of light and color-vision makes it evident that there is no theoretical requirement for more than three negatives, with which accurately to reproduce the color effect of every part of the spectrum, and of every natural color, provided that these negatives are made according to this principle.

[From the *American Journal of Photography*, December, 1888.]

PHOTOGRAPHY IN NATURAL COLORS.

At the last monthly meeting of the Franklin Institute, Mr. F. E. Ives read a paper on the subject of heliochromy, which was an addition to the communication made last February. We were not present, but see it stated in the *Philadelphia Ledger* that illustrations were shown which seemed to fully confirm Mr. Ives' claims as to the efficiency of his process. Most of the first part of the paper was devoted to the theory of light and color-sensation, and included numerous brief extracts from a recent text-book on color, which were quoted for the purpose of showing that the method, as now practised, is in strict accordance with the recognized scientific facts. He concluded as follows:

"After experimenting with several sets of reproduction pigments, adjusting color-screens so that I could make the process counterfeit the spectrum with any set of pigments, I finally adopted reproduction colors which call for negatives of the spectrum showing curves of intensity approximating to the curves in Maxwell's diagram, illustrating the action of the spectrum upon the different sets of nerve fibrils. These reproduction colors are certain shades of red, green and blue light, or their complementary colors in pigments, which approximate to Prussian blue, magenta red and aniline yellow, the first two of so light a shade that it is necessary to superimpose one upon the other to obtain a full violet blue, the blue upon the yellow to obtain green, and the magenta upon yellow to obtain red.

"When I made my first communication upon the subject I assumed, with Helmholtz, that there might be some latitude in the selection of type (reproduction) colors, and therefore did not commit myself to the use of any particular ones, but merely showed how I would produce at will negatives of the spectrum having any curves of intensity that might be required, in order to secure the proper distribution of such colors or pigments as were selected. The adoption of reproduction colors, corresponding to what are now recognized to be primary color-sensations, has made it possible for me to state more definitely my mode of procedure, as above.

"What I claim as new and original in my method is (1) the production of heliochromic negatives by exposing color-sensitive plates through com-

pound color-screens, which have been adjusted to secure negatives showing curves of intensity which bear a certain definite relation to the colors employed to produce the heliochromic pictures; and (2) the production of heliochromic negatives by a procedure calculated to yield negatives of the spectrum, showing curves of intensity which probably correspond to the action of the spectrum upon the sets of nerve fibrils.

"Admitting the theoretical soundness of my mode of procedure, which I believe I have fairly demonstrated, there remains only the question of practicability and commercial value to be considered. The process is practicable, if the same operations, repeated in the same manner, can be relied upon to produce pictures which counterfeit the light and shade and color of all objects. Three subjects which I shall show to-night, a delicate oil-painting, a brilliant Prang chromo, and a beautiful sea-shell, were made with the same light, same camera, same preparation of sensitive plates, same set of color-screens, same relative exposures and same development. They show a very great variety of colors, mostly compound in the painting and chromo, but pure spectrum colors in the sea-shell; yet the colors of all are alike faithfully counterfeited to the eye. Although there should be no question of the fact, I will here state that these finished results have been obtained without any retouching or artificial manipulation whatever."